Marijuana Primes, Marijuana Expectancies, and Arithmetic Efficiency*

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ABSTRACT. Objective: Previous research has shown that primes associated with alcohol influence behavior consistent with specific alcohol expectancies. The present study examined whether exposure to marijuana-related primes and marijuana expectancies interact to produce similar effects. Specifically, the present study examined whether marijuana primes and marijuana expectancies regarding cognitive and behavioral impairment interact to influence performance on an arithmetic task. **Method:** Two independent samples ($N = 260$) of undergraduate students (both marijuana users and nonusers) first completed measures of marijuana-outcome expectancies associated with cognitive and behavioral impairment and with general negative effects (Sample 2). Later in the semester, participants were exposed to marijuana-related (or neutral) primes and then completed an arithmetic task. **Results:** Results from Sample 1 indicated that participants who were exposed to marijuana-themed magazine covers performed more poorly on the arithmetic task if they expected that marijuana would lead to cognitive and behavioral impairment. Results from Sample 2 indicated that, for marijuana users, cognitive and behavioral impairment expectancies, but not expectancies regarding general negative effects, similarly moderated arithmetic performance for participants exposed to marijuana-related words. **Conclusions:** Results support the hypothesis that the implicit activation of specific marijuana-outcome expectancies can influence cognitive processes. Implications for research on marijuana are discussed. (*J. Stud. Alcohol Drugs* **70:** 391-399, 2009)

MARIJUANA IS THE ILLICIT DRUG most commonly used by American youth. In a nationally representative survey, more than half (52.4%) of those ages 18-25 reported having used marijuana at least once (Substance Abuse and Mental Health Administration, 2007). Research has shown that marijuana intoxication can lead to a variety of negative outcomes, including deficits in attentional and memory processes (Fried et al., 2005; Heishman et al., 1997; Hooker and Jones, 1987; Makela et al., 2006) and various behavioral impairments (Liguori et al., 2002; for reviews, see Earleywine, 2002; Iversen, 2003; Solowij, 1998).

Although research has begun to elucidate the pharmacological basis of marijuana's acute effects (e.g., Loeber and Yurgelun-Todd, 1999), it is less clear to what extent expectancies about marijuana use influence changes in cognition and behavior. The present investigation constituted an attempt to cast light on this issue by examining whether some negative consequences of acute marijuana use may be engendered by the implicit activation of marijuana-outcome expectancies.

The present study builds on recent research showing that exposure to alcohol-related primes (e.g., pictures or words associated with alcohol) interact with specific alcohol expectancies to influence thoughts, feelings, and behaviors (Bartholow and Heinz, 2006; Friedman et al., 2005, 2007). In the present study, we examined whether exposure to marijuana-related primes leads to cognitive changes—specifically decreases in arithmetic ability—consistent with individuals' expectations regarding the effects of marijuana use.

Marijuana-outcome expectancies

Substance-use expectancies are broadly defined as the reinforcing or punishing outcomes anticipated from alcohol or drug use. Such expectancies encompass several domains, including sexual, social, physical, and cognitive outcomes. Considerable research has focused on outcome expectancies regarding alcohol consumption (for reviews, see Goldman et al., 1999; Jones et al., 2001). Studies suggest, however, that expectancies related to marijuana use function in similar ways (Aarons et al., 2001; Schafer and Brown, 1991). For example, it has been shown that specific marijuana expectancies are endorsed by users and nonusers, negative expectancies are associated with decreased lifetime marijuana use, and positive marijuana expectancies are associated with increased use (Schafer and Brown, 1991).

Substance-use expectancy activation and nonconsumptive behaviors

Balanced placebo design studies have shown that the belief that one has consumed alcohol can influence behaviors in

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line with expectations associated with alcohol consumption. For example, the belief that one has consumed alcohol has been shown to lead to increased hostility (Lang et al., 1975), sexual desire (George and Marlatt, 1986), and relaxation (Wilson and Abrams, 1977). Although alcohol–placebo studies have demonstrated expectancy influences on behavior, comparatively little research has examined marijuana within a placebo paradigm. However, Kirk and colleagues (1998) reported that participants who thought that they consumed a cannabinoid capsule expressed enhanced pleasurable effects and increased heart rate after consumption, compared with participants in the control group. Similarly, Jones (1971) reported that many subjects in a placebo condition reported feeling equally “stoned,” compared with people who consumed marijuana. Although the researchers did not assess specific marijuana expectancies, the findings suggest that expectancies can influence subjective and, perhaps, physiological responses associated with marijuana consumption.

Even in the absence of real or expected consumption, expectancies have been shown to influence cognition and behavior (Bartholow and Heinz, 2006; Friedman et al., 2005, 2007). Friedman and colleagues (2005) tested whether exposure to alcohol primes influenced behaviors associated with sexual arousal. The participants, all men, were first exposed to words related to either alcohol or control beverages. After the priming task, the participants completed an ostensibly unrelated study in which they rated the attractiveness or intelligence of women based on their photographs. Results showed that holding expectancies that alcohol would increase sexual arousal led to higher attractiveness ratings for the participants exposed to the alcohol primes, compared with the participants in the control condition. More recently, Friedman and colleagues (2007) showed that participants who were exposed to alcohol-related primes behaved more aggressively toward a confederate if they held expectancies that alcohol would make them aggressive.

Although Friedman and colleagues (2005, 2007) have demonstrated that activating alcohol expectancies can alter nonconsumptive behavior (e.g., aggression), no studies thus far had examined whether the activation of marijuana expectancies similarly engenders expectancy-consistent behavior. The present study addresses this issue by examining whether the activation of specific marijuana expectancies—in the absence of either actual or placebo marijuana use—fosters aspects of cognitive functioning expected to result from marijuana consumption.

Overview of present study

In the present study, the participants were exposed to primes associated with marijuana. After the priming task, the participants completed an arithmetic task. This task was chosen because research has shown that people who are under the influence of marijuana often perform worse on arithmetic tasks, compared with people in a control condition (see Earleywine, 2002; Iversen, 2003; Solowij, 1998). We hypothesized an interaction between priming condition and marijuana-outcome expectancies. Specifically, we predicted that individuals who were exposed to marijuana primes would perform more poorly on the arithmetic task if they held strong expectancies that acute marijuana use leads to cognitive and behavioral impairment (CBI).

Method

Participants

Students enrolled in an introductory psychology course participated for partial completion of course credit. Sample 1 included 101 participants (49% female). Sample 2 included 159 participants (55% female). The participants ranged in age from 18 to 24 (mean [SD] = 18.82 [0.95]) and were predominantly white (85%) and non-Hispanic (98%). For Sample 1, two participants who reported some suspicion about the purpose of the study were excluded from the analyses. For Sample 2, the data for four participants who reported some suspicion were dropped from the analyses.

Measures

Expectancy assessment. To measure marijuana-outcome expectancies, the participants completed the CBI subscale of the Marijuana Effect Expectancy Questionnaire (Aarons et al., 2001; Schafer and Brown, 1991). This is a 48-item questionnaire that assesses six different domains of individuals' positive and negative expectancies regarding the acute effects of marijuana use. The nine-item CBI subscale assesses beliefs related to impairments in cognitive and behavioral functioning if one were under the influence of marijuana (e.g., “Marijuana slows thinking and actions” and “Things seem unreal and I feel out of touch with what's going on around me when I smoke marijuana”). The CBI subscale of the Marijuana Effect Expectancy Questionnaire has been shown to have good internal consistency reliability (Kuder-Richardson-20 = .76) and validity in previous studies (Schafer and Brown, 1991). All items were rated on a 1 (disagree strongly) to 5 (agree strongly) scale (Sample 1: mean = 3.55 [0.87]; α = .78; Sample 2: mean = 3.41 [0.63]; α = .83).

In Sample 2, we also used the nine-item global negative effects subscale of the Marijuana Effect Expectancy Questionnaire (Schafer and Brown, 1991; mean = 2.77 [0.68]; α = .86) to assess other negative marijuana expectancies that were not specifically related to CBI. The inclusion of this subscale allowed us to examine whether specific expectancies related to cognitive and behavioral deficits would influence the predicted effects or whether individual differences in negative marijuana expectancies in general would lead to similar outcomes.

Experimental manipulation (Sample 1): A "Magazine Preference Task" served as a means of priming Sample 1 participants. For this task, the participants were told that the experimenters were interested in college students' beliefs and attitudes about various types of magazines. The participants were first asked to view a "random" magazine cover and then to answer various questions related to the magazine. The magazine cover was first displayed for 45 seconds. After the initial viewing of the magazine, the cover remained on the screen while the participants rated the magazine on various dimensions (e.g., "How many people do you think subscribe to this magazine in the United States?" "Have you ever read an article from this magazine?" and "Do you think the magazine will still be available in 10 years?"). To further help bolster the cover story, participants first viewed (and rated) two "filler" magazine covers.

In the experimental condition, the third magazine cover was from High Times. This magazine cover featured a picture of a marijuana plant as well as various references to marijuana such as "Cannabis bowl preview" and "Indoor guide to ganja growing."

In the control condition, the third magazine cover was from Garden Ideas and Outdoor Living. This magazine cover featured an assortment of common backyard vegetation, as well as various references to gardening such as "Grow big color in a small place." These particular High Times and Garden Ideas and Outdoor Living magazine covers were selected because they were roughly equivalent in terms of layout and picture/text ratio and did not contain explicit reference to any cognitive or emotional states (e.g., "relaxed," "mellow," "burnt-out") that might have influenced the outcome measures.

Experimental manipulation (Sample 2): The participants in Sample 2 completed a lexical decision task as the priming mechanism. The technique has been used in previous research examining interactions between alcohol primes and expectancies (Friedman et al., 2005, 2007). For this task, the participants were asked to categorize various stimuli as either words (by pressing the "Z" key) or nonwords (by pressing the "/" key). They were additionally instructed that a random string of letters would appear before each stimulus was presented and that "we [were] interested in how the presentation of the random stimuli influences subsequent lexical decisions." The participants were told to respond as quickly as possible. Each trial began with a "+" presented in the middle of the screen for 1000 ms. To ensure that the participants' attention was directed at the primed words, they were instructed to stare at the "+" presented in the middle of the screen to help them respond as quickly as possible. The amount of processing of the primed stimuli was diminished by focusing the participants' attention on the lexical decision task. After the "+," a string of "&"s was displayed for 400 ms. Then, after the string of "&"s was presented, the primed words were presented suboptimally for 40 ms. This suboptimal priming technique was used to limit the extent that individuals processed the primed stimuli. Although this is not a subliminal priming technique per se, past research using this technique has shown that most individuals are unable to consciously identify the primed words (e.g., Friedman et al., 2007; for a review, see Bargh and Chartrand, 2000).

The participants in each condition were primed with words that were roughly equivalent in terms of length. In the experimental condition, the participants were primed with words related to marijuana such as "bong," "joint," "reefer," "high," "weed," and "blunt." In the control condition, the participants were primed with words for different animals such as "bear," "zebra," "ferret," "lion," "llama," and "tiger." Immediately after the primes were presented, a string of "X"s was presented for 400 ms to serve as a backward mask. This additionally helped to limit the amount of time spent processing the marijuana and control primes. After the string of letter "X"s was displayed, the participants were presented with another letter string, which served as the stimulus for their lexical decision (e.g., "irony" or "nogzp"). There were a total of 110 lexical decision trials.

Arithmetic task. The participants also completed a task purportedly examining "mental math solving abilities of college students." The participants were instructed that random addition and subtraction problems would appear on the screen, and the task was to complete each problem without the use of any aid (e.g., pen and paper, calculator). They were instructed further that they would have 30 seconds to complete each problem and that they should try to solve the problems as quickly as possible. After finishing each problem, the participants were instructed to hit the "Enter" key to advance to the next problem. The screen automatically advanced if they did not complete the problem within the time limitation. Examples of the arithmetic problems include "56 + 71 – 13" and "63 – 18 + 78." There were 12 arithmetic problems. Unbeknownst to the participants, the computer automatically recorded the amount of time spent on each problem. Overall, the participants answered a majority of the problems correctly (Sample 1: mean = 8.67 [2.29]; Sample 2: mean = 8.68 [2.02]), and they spent a relatively short amount of time on each problem (Sample 1: mean = 14.57 [3.80] seconds; Sample 2: mean = 13.10 [3.11] seconds).

Mood measure. To assess mood, the participants completed four items related to their "thoughts and feelings about the experiment so far." Two items were related to their current mood, including "How relaxed do you feel right now?" (1 = very tense, 7 = very relaxed; Sample 1: mean = 5.46 [1.20]; Sample 2: mean = 4.90 [1.20]) and "How anxious do you feel right now?" (1 = very anxious, 7 = very calm; Sample 1: mean = 5.29 [1.40]; Sample 2: mean = 4.63 [1.41]). The mean of the two items was averaged to create a composite mood variable (Sample 1: mean = 5.37 [1.20], $r = .69$; Sample 2: mean = 4.77 [1.18], $r = .63$).

Marijuana use. The participants also completed a variety of filler questionnaires. The last questionnaire was ostensibly sponsored by "The University of Missouri–Columbia's Center for Research on Addictions." Three items embedded in this survey assessed lifetime, past-year, and past-month frequency of marijuana use. Forty-eight percent of the participants in Sample 1 ($n = 48$) and 46% of the participants in Sample 2 ($n = 72$) reported smoking marijuana at least once in their lifetime. Forty-three percent of the participants in both Sample 1 ($n = 43$) and Sample 2 ($n = 66$) reported smoking marijuana at least once in the past year. Twenty-six percent of the participants in Sample 1 ($n = 26$) and 24% of the participants in Sample 2 ($n = 37$) reported smoking marijuana at least once in the past month.

Procedure

At the beginning of the semester, the participants completed a mass pretest that included a variety of diverse measures (approximately 300 items). Embedded in the pretest was the CBI subscale of the Marijuana Effect Expectancy Questionnaire. Approximately 1 month later, the participants completed a laboratory session. On arrival, they were escorted by the experimenter to a visually isolated computer, and they were randomly assigned to the experimental or control condition. To help bolster the cover story, they were told that they would complete a few unrelated tasks purportedly sponsored by various researchers from the psychology department. The first task was the experimental manipulation, followed by the arithmetic task and the mood measure. The participants then completed a variety of filler questionnaires unrelated to substance use, followed by the survey containing the items related to previous marijuana use, and, in Sample 2, the global negative effects subscale of the Marijuana Effect Expectancy Questionnaire. The global negative effects subscale was not administered during the same assessment as the CBI subscale because of limitations in the number of items that could be included in the pretest. Finally, the participants were probed for suspicion, and they were fully debriefed.

Plan of analyses

There were two primary dependent variables: The first was the total number of mathematics problems answered correctly. The second was the average amount of time it took the participants to answer the problems that they solved correctly. This variable was used rather than the average time to complete all problems (i.e., including problems answered incorrectly), because, although some incorrect responses were the result of the inability to complete the problem within the constraint, others may have been caused by different factors (e.g., carelessness or lack of motivation).

A series of hierarchical multiple regression equations were conducted to test hypotheses for the two dependent variables (number correctly completed and average time to completion). CBI expectancy scores were centered for these analyses. The product of the centered expectancy scores and condition (0 = control, 1 = experimental) was used as the interaction term (Aiken and West, 1991). All analyses controlled for mood. Although we did not predict that the manipulations would influence mood, controlling for this possibility was necessary, given that mood has been shown to influence performance on tasks that involve analytical thinking (see Fiedler, 2001; Schwarz, 2002). For Sample 1, marijuana use was included as a covariate, as frequency of marijuana use is strongly associated with marijuana expectancy endorsement (Schafer and Brown, 1991). *Marijuana-user status* was defined as smoking marijuana at least once in the past year (0 = no, 1 = yes). We chose to analyze the results using this categorical variable, because the variable of frequency of marijuana use was highly skewed and zero-inflated (as a significant number of participants reported not smoking marijuana in the past year). However, the results of all significant interactions reported in both studies remained significant when the categorical marijuana use variable was replaced with a continuous marijuana use variable (p's < .05).

For Sample 2, we additionally tested for potential differences between marijuana users and the participants who had either never smoked marijuana or who had not smoked marijuana in the past year. We were able to test this potential difference in Sample 2 because of the added statistical power owing to the increased sample size. To test this possibility, we created a total of 3 two-way interaction terms by taking the products of centered expectancy scores, condition (0 = control, 1 = experimental), and marijuana-user status (0 = no, 1 = yes), as well as a three-way interaction term by taking the product of all three variables. All significant effects are reported in the following analyses.

Results

Correlational analyses indicated that, for Sample 1, CBI expectancies and solution total were significantly correlated with solution speed (r's = .19 and -.35, respectively, p's < .05). For Sample 2, global negative effects expectancies were significantly associated with solution total ($r = -.15$, $p < .05$), and solution total was significantly correlated with solution speed ($r = -.18$, $p < .05$). No other significant relationships emerged in these analyses.

Primary analyses (Sample 1)

The first analysis examined whether primes interacted with CBI expectancies to predict the number of problems answered correctly. Mood and marijuana-user status were

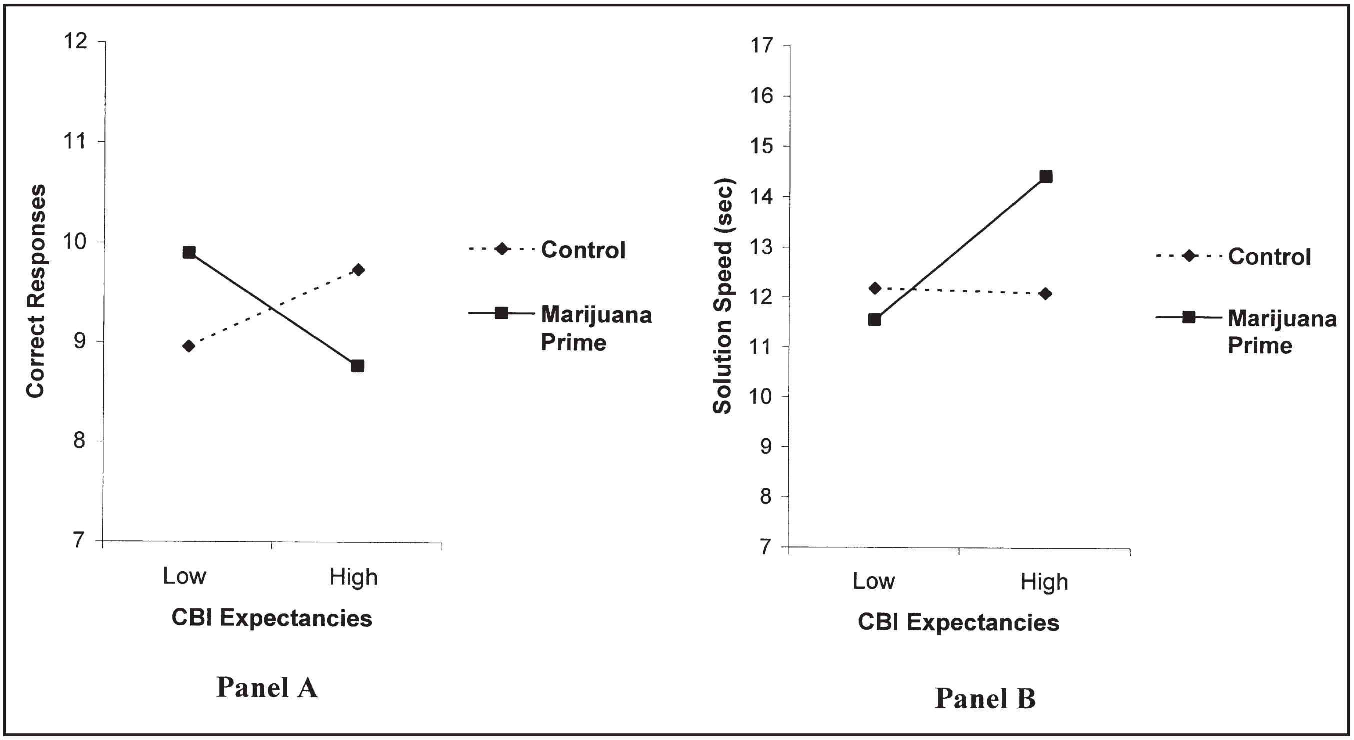

FIGURE 1. Correct responses (Panel A) and solution speed (Panel B) as a function of supraliminal primes and marijuana cognitive and behavioral impairment (CBI) expectancies (n = 99), Sample 1; sec = seconds

entered on the first step as control variables. These variables did not contribute to a significant change in R^2 (R^2_{change} = .02, p = .37). The main effects, entered on the second step, similarly did not lead to a significant change in R^2 (R^2_{change} = .00, p = .88). However, as expected, the interaction term, entered on the third step, did produce a significant change in R^2 (R^2_{change} = .04, $p < .05$; β = -.30, $p < .05$). Inspection of the slopes of the two conditions revealed the hypothesized effects. CBI expectancies were unrelated to math scores in the control condition (β = .14, p = .34, two tailed) and were negatively associated with math scores in the marijuana-priming condition (β = -.25, $p < .05$, one tailed). The generated means (±1 SD) for this interaction are shown in Panel A of Figure 1.

We next tested whether primes and CBI expectancies interacted to predict average solution speed. The control variables, entered on the first step, did not contribute to a significant change in R^2 (R^2_{change} = .02, p = .40). The main effects, entered on the second step, contributed to a marginally significant change in R^2 (R^2_{change} = .05, p = .07). Again, as predicted, the interaction term, entered on the third step, produced a significant change in R^2 (R^2_{change} = .04, $p < .05$; β = .30, $p < .05$), showing that, although CBI expectancy ratings were not related to solution speed in the control condition (β = -.01, p = .97), expectancy ratings were related to solution speed in the marijuana-prime condition (β = .43, $p < .001$). Participants in the marijuana-prime condition who held higher CBI expectancies took longer to complete correctly solved arithmetic problems, compared with participants in the control condition. The generated means for this interaction are shown in Panel B of Figure 1.

Primary analyses (Sample 2)

The first analysis in Sample 2 examined the effects of condition, expectancies, and previous marijuana use on the number of problems answered correctly. Mood was entered on the first step as a control variable and did not contribute to a significant change in R^2 (R^2_{change} = .00, p = .42). Neither the main effects, entered on the second step (R^2_{change} = .04, p = .18), nor the two-way interaction terms, entered on the third step (R^2_{change} = .03, p = .16), contributed to a significant change in R^2. However, the three-way interaction term, entered on the fourth step, did produce a significant change in R^2 (R^2_{change} = .03, $p < .05$; β = -.32, $p < .05$).

To probe the three-way interaction, we separated the participants by marijuana-smoking status and inspected the two-way interactions. For the participants who were not marijuana users, none of the effects were significant (p's > .23). For the participants who had experience smoking marijuana in the past year, the effect of mood, entered on the first step, did not contribute to a significant change in R^2

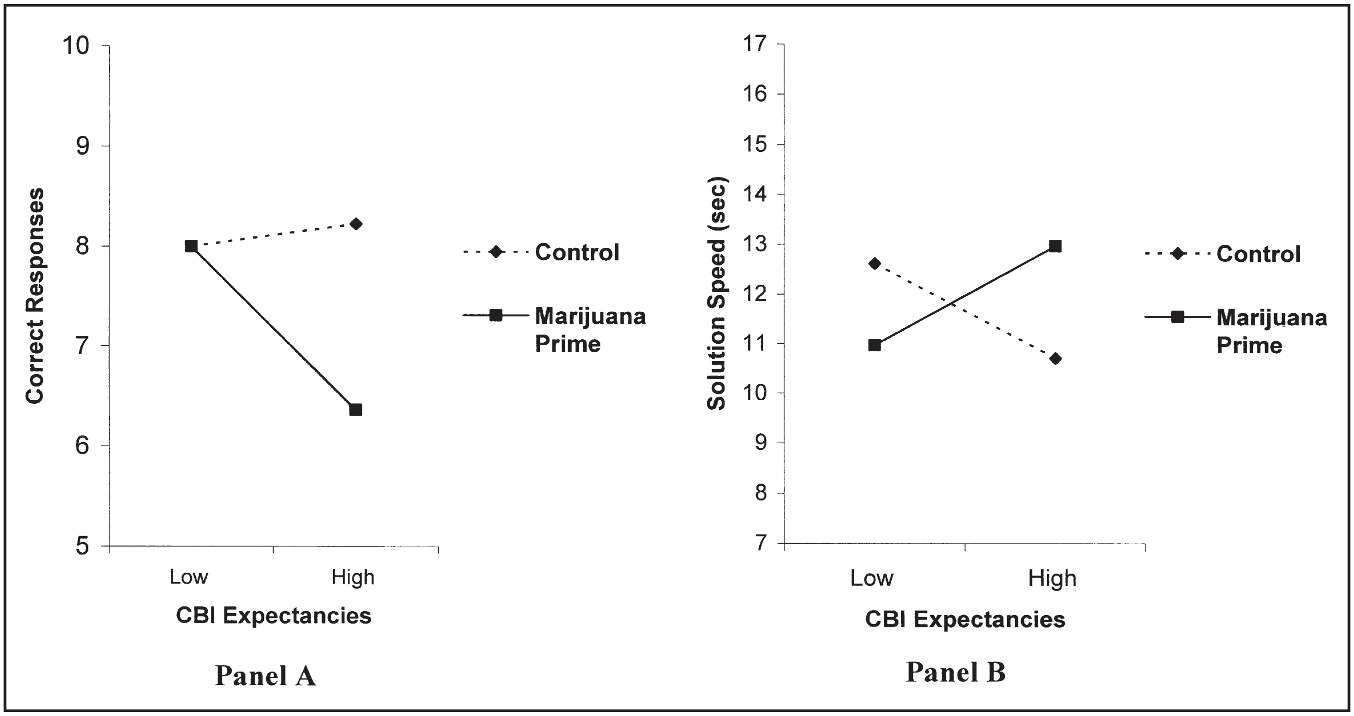

FIGURE 2. Correct responses (Panel A) and solution speed (Panel B) for past-year marijuana users as a function of suboptimal primes and marijuana cognitive and behavioral impairment (CBI) expectancies (n = 66), Sample 2; sec = seconds

(R^2_{change} = .04, p = .14). The main effects, entered on the second step, contributed to a significant change in R^2 (R^2_{change} = .11, $p < .05$), with condition predicting correct responses (β = .31, $p < .05$). This main effect, however, was qualified by a predicted two-way interaction entered on the third step R^2 (R^2_{change} = .05, $p < .03$, one tailed; β = .35, $p < .03$, one tailed). In line with predictions, inspection of the slopes for the two conditions revealed that CBI expectancies were not related to the number of correct answers in the control condition (β = .08, p = .82), and, as expected, CBI expectancies were negatively related to the number of correct answers in the experimental condition (β = -.40, $p < .01$), such that higher CBI expectancies predicted lower scores on the arithmetic task. The generated means (±1 SD) for this interaction are shown in Panel A of Figure 2.

We next examined the effects of condition, expectancies, and previous marijuana use on solution speed. Again, mood was entered on the first step as a control variable and did not contribute to a significant change in R^2 (R^2_{change} = .00, p = .41). The main effects, entered on the second step, did lead to a significant change in R^2 (R^2_{change} = .07, $p < .05$), with marijuana-user status predicting solution speed (β = -.27, $p < .05$). The two-way interaction terms entered on the third step did not lead to a significant change in R^2 (R^2_{change} = .03, p = .19). Once again, however, the three-way interaction term, entered on the fourth step, did produce a significant change in R^2 (R^2_{change} = .04, $p < .05$; β = -.32, $p < .05$).

To inspect the three-way interaction, we again separated the participants by marijuana-user status. No significant effects were found in the sample of participants who had not smoked marijuana in the past year (p's > .28). For the sample who had smoked marijuana in the past year, the effect of mood, entered on the first step, did not contribute to a significant change in R^2 (R^2_{change} = .02, p = .24). The main effects, entered on the second step, also did not lead to a significant change in R^2 (R^2_{change} = .03, p = .35). As predicted, however, the two-way interaction entered on the third step did contribute to a significant change in R^2 (R^2_{change} = .08, $p < .05$; β = .45, $p < .01$). This interaction showed that, although expectancy scores were not associated with solution speed in the control condition (β = -.19, p = .27), they were associated with solution speed in the experimental condition (β = .36, $p < .05$). This interaction parallels the findings from Sample 1, showing that the participants who were primed with words related to marijuana took longer to solve the arithmetic problems if they expected that they would be cognitively or behaviorally impaired after smoking marijuana. The generated means for this interaction are shown in Panel B of Figure 2.

Similar regression analyses also examined whether primes and user status interacted with global negative effects expectancies to influence performance. Results revealed that these expectancies did not interact with condition, user status, or both to influence the number of arithmetic problems answered correctly or the solution speed (for the three-way interactions, *p*'s > .16). These null findings suggest that the cues interacted with the CBI expectancies specifically to influence performance.

Discussion

Overall, the results of the present study converge with recent findings in the alcohol literature showing that exposure to rudimentary situational primes can interact with specific expectancies to influence cognition and behavior (Bartholow and Heinz; 2006; Friedman et al., 2005, 2007). The present study provides evidence that exposure to primes associated with marijuana can detrimentally influence performance on a subsequent arithmetic task for those with expectancies that cognitive abilities and behavior will be adversely affected by smoking marijuana. In Sample 1, the results showed that those individuals exposed to marijuana primes (via a marijuana-themed magazine) showed diminished performance on a subsequent arithmetic task if they held strong expectancies that marijuana use leads to cognitive or behavioral impairment. Using a subtle priming technique, Sample 2 showed that arithmetic efficiency was diminished for those who were exposed to marijuana primes and expected that marijuana use would lead to CBIs. Importantly, in Sample 2, this pattern of results was evident only for those who had experience smoking marijuana in the past year.

The present findings are consistent with those of numerous studies in the field of social cognition (e.g., Bargh and Chartrand, 1999; Bargh et al., 1996; Dijksterhuis and Bargh, 2001). Many researchers believe that representations in long-term memory are associated with behavioral scripts, or plans for how behavior related to these representations should be enacted. It is believed that activation of a mental construct, either consciously or unconsciously, also will activate the behavioral scripts associated with the mental construct. This, in turn, influences behavior in line with those beliefs. The results of the present studies and numerous others (e.g., Aarts and Dijksterhuis, 2003; Bargh et al., 2001) provide compelling evidence that the implicit activation of specific knowledge structures can lead to complex cognitive changes.

Importantly, there were no main effects of the marijuana primes. Instead, the primes interacted with marijuana expectancies to influence behavior. These findings suggest that individuals' expectancies are inherently associated with the content of the particular mental construct that is activated. Supporting this idea is research showing that primed words related to the elderly (e.g., "gray," "bingo," "old") lead to impairment on memory tasks only to the extent to which the individual has a strong association between the elderly and the stereotype of forgetfulness (Dijksterhuis et al., 2000).

In a related vein, in Sample 2, only people who had smoked marijuana in the past year were influenced by the marijuana cues. In fact, exposure to the experimental primes did not influence performance for those who had not smoked marijuana in the past year. Several possible explanations exist for this finding. For example, it is believed that greater experience with a substance can facilitate the activation of expectancy associations (Goldman, 1999). Therefore, individuals who have not had experience using marijuana in the past year may have been less affected by the (subtle) primes used in Sample 2, compared with individuals with marijuana expectancies that are based on recent experience and are, therefore, more easily activated. It also is possible that the suboptimal priming technique led to weaker (and ultimately nonsignificant) effects for people who have not used marijuana in the past year, because the primed words in the task activated more non-marijuana-related concepts, such as those related to culinary endeavors ("baked," "pot"), heights ("high"), vegetation ("weed," "bud"), whereas the same words may have activated concepts more centrally associated with marijuana use for those who had more recent experience smoking marijuana. This finding is consistent with studies of word or object associations, which find that heavier users are more likely to interpret ambiguous stimuli as drug related (e.g., Stacy, 1997; see also Stacy, 1995).

Future research needs to examine the extent to which the activation of marijuana expectancies influences behavior over and above the pharmacological effects of marijuana intoxication (e.g., Loeber and Yurgelun-Todd, 1999). Currently, it is unclear to what extent the behavioral changes associated with acute marijuana use can be attributed to explicit expectancy activation. The results of the present studies suggest, at minimum, that marijuana expectancies need to be assessed during marijuana-administration studies to help tease apart the effects of marijuana-expectancy activation and the pharmacological effects of marijuana intoxication on behavior.

To our knowledge this is the first study to directly test the influence of marijuana-expectancy activation on subsequent behavior. Although these findings largely parallel those found in the alcohol literature (Bartholow and Heinz; 2006; Friedman et al., 2005, 2007), some differences emerged. Specifically, in Sample 2, marijuana expectancies interacted with marijuana primes only for recent marijuana smokers. In the alcohol literature, both users and nonusers of alcohol seem to be influenced by alcohol primes in this type of paradigm (see also Zack et al., 1999). Additional research is needed to directly compare alcohol and marijuana within this paradigm to more directly assess potential differences in these drugs.

The present study is limited by a number of factors. First, the study included only a relatively small sample of college students. Although many college students have reported using marijuana at least once in their lifetime (Substance Abuse and Mental Health Administration, 2007), it is unclear, for example, whether a sample of chronic marijuana users or adult marijuana users would have been similarly influenced by the priming tasks. Clearly, these findings require replication with a different sample of participants. Second, the current study examined only one domain of functioning, CBI. Further work is needed to determine whether a similar process may operate for more "positive" outcomes of consuming marijuana (e.g., creativity, relaxation).

Despite these limitations, the present results have important implications for research on marijuana use. As previously mentioned, marijuana intoxication has been shown to have many adverse consequences on cognitive and behavioral functioning (for reviews, see Earleywine, 2002; Iversen, 2003; Solowij, 1998). Previous research has shown that challenging alcohol expectancies can result in decreased drinking behavior (e.g., Darkes and Goldman, 1998; Wiers and Kummeling, 2004; Wood et al., 2007). A similar technique may be useful for marijuana interventions "challenging" people's positive marijuana expectancies.

Additionally, these results suggest that marijuana-expectancy effects should be incorporated into drug-education programs. Although it is clear that the pharmacological effects of marijuana use can have adverse consequences on cognitive and behavioral functioning, people should be aware as well that their expectancies regarding the effects of this drug also can influence their behavior.

References

Aarons, G.A., Brown, S.A., Stice, E., and Coe, M.T. Psychometric evaluation of the Marijuana and Stimulant Effect Expectancy Questionnaires for adolescents. Addict. Behav. **26:** 219-236, 2001.

Aarts, H. and Dijksterhuis, A. The silence of the library: Environment, situational norm, and social behavior. J. Pers. Social Psychol. **84:** 18-28, 2003.

Aiken, L.S. and West, S.G. Multiple Regression: Testing and Interpreting Interactions. Thousand Oaks, CA: Sage, 1991.

Bargh, J.A. and Chartrand, T.L. The unbearable automaticity of being. Amer. Psychol. **54:** 462-479, 1999.

Bargh, J.A. and Chartrand, T.L. A practical guide to priming and automaticity research. In: Reiss, H.T. and Judd, C.M. (Eds.) Handbook of Research Methods in Social Psychology, New York: Cambridge Univ. Press, 2000, pp. 253-285.

Bargh, J.A., Chen, M., and Burrows, L. Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. J. Pers. Social Psychol. **71:** 230-244, 1996.

Bargh, J.A., Gollwitzer, P.M., Lee-Chai, A., Barndollar, K., and Trotschel, R. The automated will: Nonconscious activation and pursuit of behavioral goals. J. Pers. Social Psychol. **81:** 1014-1027, 2001.

Bartholow, B.D. and Heinz, A. Alcohol and aggression without consumption: Alcohol cues, aggressive thoughts, and hostile perception bias. Psychol. Sci. **17:** 30-37, 2006.

Darkes, J. and Goldman, M.S. Expectancy challenge and drinking reduction: Process and structure in the alcohol expectancy network. Exp. Clin. Psychopharmacol. **6:** 64-76, 1998.

Dijksterhuis, A., Aarts, H., Bargh, J.A., and van Knippenberg, A. On the relation between associative strength and automatic behavior. J. Exp. Social Psychol. **36:** 531-544, 2000.

Dijksterhuis, A., and Bargh, J.A. The perception-behavior expressway: Automatic effects of social perception on social behavior. In: Zanna M.P. (Ed.) Advances in experimental social psychology, San Diego: Academic Press, 2001, pp. 1-40.

Earleywine, M. Understanding Marijuana: A New Look at Scientific Evidence, New York: Oxford Univ. Press, 2002.

Fiedler, K. Affective influences on social information processing. In: Forgas, J.P. (Ed.) Handbook of Affect and Social Cognition, Mahwah, NJ: Lawrence Erlbaum, 2001, pp. 163-185.

Fried, P.A., Watkinson, B., and Gray, R. Neurocognitive consequences of marihuana: A comparison with pre-drug performance. Neurotoxicol. Teratol. **27:** 231-239, 2005.

Friedman, R.S., McCarthy, D.M., Bartholow, B.D., and Hicks, J.A. Interactive effects of alcohol outcome expectancies and alcohol cues on nonconsumptive behavior. Exp. Clin. Psychopharmacol. **15:** 102-114, 2007.

Friedman, R.S., McCarthy, D.M., Forster, J., and Denzler, M. Automatic effects of alcohol cues on sexual attraction. Addiction **100:** 672-681, 2005.

George, W.H. and Marlatt, G.A. The effects of alcohol and anger on interest in violence, erotica, and deviance. J. Abnorm. Psychol. **95:** 150-158, 1986.

Goldman, M.S. Risk for substance abuse: Memory as a common etiological pathway. Psychol. Sci. **10:** 196-198, 1999.

Goldman, M.S., Darkes, J., and Del Boca, F.K. Expectancy mediation of biopsychosocial risk for alcohol use and alcoholism. In: Kirsch, I. (Ed.) How Expectancies Shape Experience, Washington, DC: American Psychological Assn, 1999, pp. 233-262.

Heishman, S.J., Arasteh, K., and Stitzer, M.L. Comparative effects of alcohol and marijuana on mood, memory, and performance. Pharmacol. Biochem. Behav. **58:** 93-101, 1997.

Hooker, W.D. and Jones, R.T. Increased susceptibility to memory intrusions and the Stroop interference effect during acute marijuana intoxication. Psychopharmacology **91:** 20-24, 1987.

Iversen, L. Cannabis and the brain. Brain **126** (Pt 6): 1252-1270, 2003.

Jones, B.T., Corbin, W., and Fromme, K. A review of expectancy theory and alcohol consumption. Addiction **96:** 57-72, 2001.

Jones, R.T. Marijuana-induced "high": Influence of expectation, setting and previous drug experience. Pharmacol. Rev. **23:** 359-369, 1971.

Kirk, J.M., Doty, P., and de Wit, H. Effects of expectancies on subjective responses to oral Δ9-tetrahydrocannabinol. Pharmacol. Biochem. Behav. **59:** 287-293, 1998.

Lang, A.R., Goeckner, D.J., Adesso, V.J., and Marlatt, G.A. Effects of alcohol on aggression in male social drinkers. J. Abnorm. Psychol. **84:** 508-518, 1975.

Liguori, A., Gatto, C.P., and Jarrett, D.B. Separate and combined effects of marijuana and alcohol on mood, equilibrium and simulated driving. Psychopharmacology **163:** 399-405, 2002.

Loeber, R.T. and Yurgelun-Todd, D.A. Human neuroimaging of acute and chronic marijuana use: Implications for frontocerebellar dysfunction. Human Psychopharmacol. Clin. Exp. **14:** 291-304, 1999.

Makela, P., Wakeley, J., Gijsman, H., Robson, P.J., Bhagwagar, Z., and Rogers, R.D. Low doses of Δ-9 tetrahydrocannabinol (THC) have divergent effects on short-term spatial memory in young, healthy adults. Neuropsychopharmacology **31:** 462-470, 2006.

Schafer, J. and Brown, S.A. Marijuana and cocaine effect expectancies and drug use patterns. J. Cons. Clin. Psychol. **59:** 558-565, 1991.

Schwarz, N. Situated cognition and the wisdom of feelings: Cognitive tuning. In: Barrett L.F. and Salovey P. (Eds.) The Wisdom in Feeling: Psychological Processes in Emotional Intelligence, New York: Guilford Press, 2002, pp. 144-166.

Solowij, N. Cannabis and Cognitive Functioning, New York: Cambridge Univ. Press, 1998.

Stacy, A.W. Memory association and ambiguous cues in models of alcohol and marijuana use. Exp. Clin. Psychopharmacol. **3:** 183-194, 1995.

Stacy, A.W. Memory activation and expectancy as prospective predictors of alcohol and marijuana use. J. Abnorm. Psychol. **106:** 61-73, 1997.

Substance Abuse and Mental Health Services Administration (Office of Applied Studies). Results From the 2006 National Survey on Drug Use and Health: National Findings, DHHS Publication No. SMA 07-4293, Rockville, MD: Substance Abuse and Mental Health Services Administration, 2007.

Wiers, R.W. and Kummeling, R.H.C. An experimental test of an alcohol expectancy challenge in mixed gender groups of young heavy drinkers. Addict. Behav. **29:** 215-220, 2004.

Wilson, G.T. and Abrams, D. Effects of alcohol on social anxiety and physiological arousal: Cognitive versus pharmacological processes. Cog. Ther. Res. **1:** 195-210, 1977.

Wood, M.D., Capone, C., Laforge, R., Erickson, D.J., and Brand, N.H. Brief motivational intervention and alcohol expectancy challenge with heavy drinking college students: A randomized factorial study. Addict. Behav. **32:** 2509-2528, 2007.

Zack, M., Toneatto, T., and MacLeod, C.M. Implicit activation of alcohol concepts by negative affective cues distinguishes between problem drinkers with high and low psychiatric distress. J. Abnorm. Psychol. **108:** 518-531, 1999.